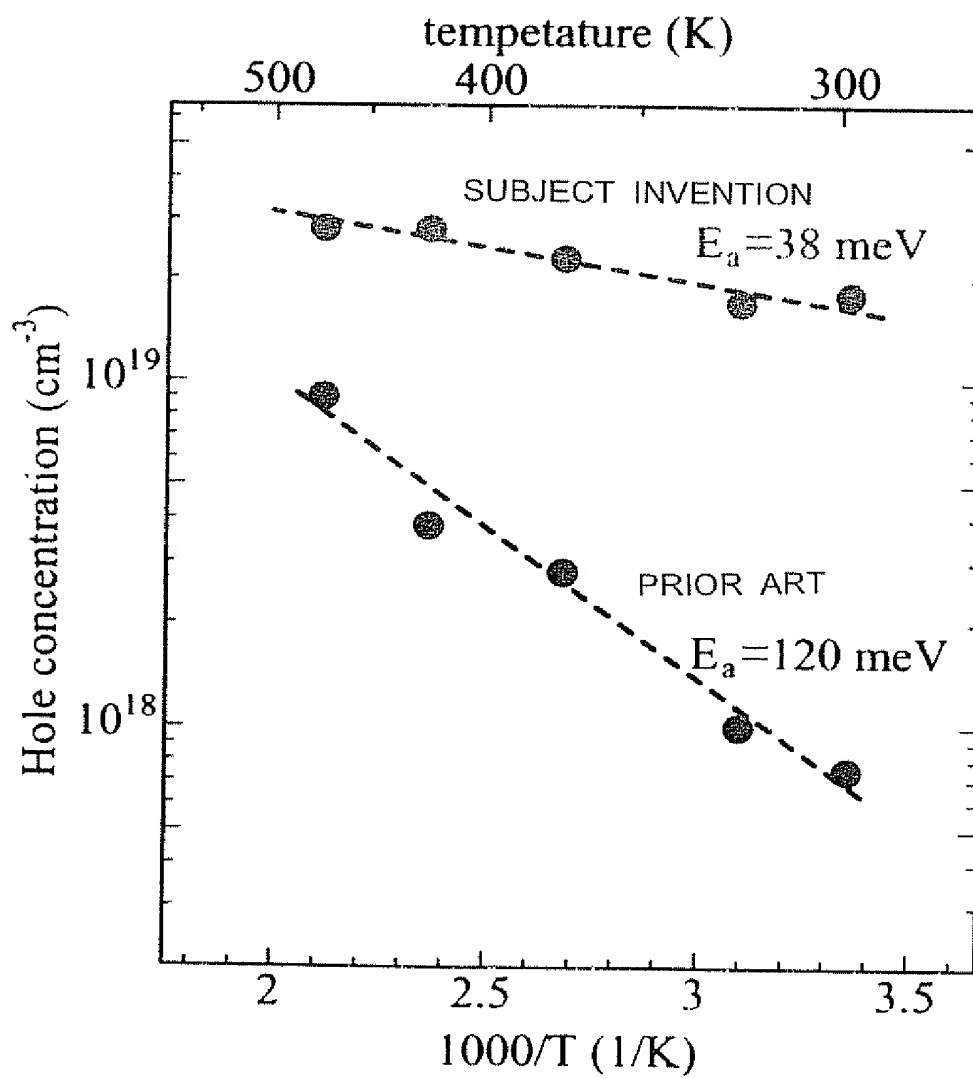


FIG. A

ACTIVATION ENERGY





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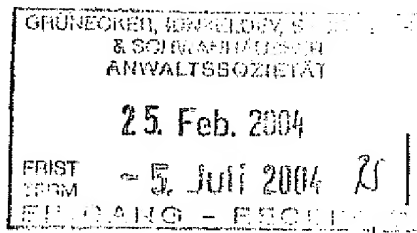
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| | | |
|---------------------------------------|------------------------|--------------------|
| Application No 01 121 026.7 - 2119 | Ref. EP22290-011/aw | Date 24.02.2004 |
| Applicant Riken | | |

Communication pursuant to Article 96(2) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(1) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 78(2) and 83(2) and (4) EPC.

One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (Rule 36(1) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Article 96(3) EPC).



KILIAAN S H
Primary Examiner
for the Examining Division

Enclosure(s): 4 page/s reasons (Form 2906)



Bescheld/Protokoll (Anlage)

Communication/Minutes (Annex)

Notification/Procès-verbal (Annexe)

Datum
Date
Date

24 . 02 . 2004

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Sheet
Feuille

1

Anmelde-Nr :
Application No. : 01 121 026 . 7
Demande n°:

The examination is being carried out on the **following application documents**:

Text for the Contracting States: AT BE CH CY DE DK ES FI FR GB GR IE IT LU MC NL PT SE TR LI

Description, pages:

1-28 as originally filed

Claims, No.:

1-25 as originally filed

Drawings, No.:

1-10 as originally filed

1. Claims 1, 2, 3, 21, 22, 23, 24 and 25 have been drafted as separate independent claims.

Under Article 84 in combination with Rule 29(2) EPC an application may contain more than one independent claim in a particular category only if the subject matter claimed falls within one or more of the exceptional situations set out in paragraphs (a), (b) or (c) of Rule 29(2) EPC.

This is not however the case in the present application.

The applicant is requested to file an amended set of claims which complies with Rule 29(2). Failure to do so, or to submit convincing arguments as to why the current set of claims does in fact comply with these provisions, will lead to refusal of the application under Article 97(1) EPC.

2. The following documents are referred to in this communication; the numbering will be adhered to in the rest of the procedure:

D1= US-A-5 693 139 (NISHIZAWA JUNICHI ET AL) 2 December 1997 (1997-12-02);

D2= US-A-5 338 389 (NISHIZAWA JUNICHI ET AL) 16 August 1994 (1994-08-16);

D3= OHUCHI Y ET AL: 'New dopant precursors for n-type and p-type GaN'
JOURNAL OF CRYSTAL GROWTH, NORTH-HOLLAND PUBLISHING CO.
AMSTERDAM, NL, vol. 170, no. 1-4, 1997, pages 325-328, XP004087127



ISSN: 0022-0248;

D4= EP-A-0 439 064 (JAPAN RES DEV CORP; KURABAYASHI TORU (JP);
NISHIZAWA JUNICHI (JP)) 31 July 1991 (1991-07-31).

- 2.1. D1 discloses a doping method for a compound semiconductor (figure 11). To form a p-type GaAs layer, TMGa and AsH₃ as main component gases and dimethylzinc (DMZn) as an impurity gas are cyclically introduced or TMGa and DMZn are introduced simultaneously but alternately with AsH₃, or AsH₃ and DMZn are introduced simultaneously but alternately with TMGa or a first cycle consisting of simultaneous introduction of AsH₃ only and evacuation, may be alternately repeated to alternately form a layer of doped with Zn and a layer not doped with Zn or to form a plurality of first layers alternated by second layers. The impurity gas may be dimethylcadmium (DMCd), dimethylmagnesium (DMMg), monosilane (SiH₄) and germane (GeH₄). Further DMCd and DMZn may be simultaneously introduced. (figure 11, column 8, lines 32 to 50).

In the light of D1, the subject-matter of claims 1 to 20, 22, 24 and 25 is not new.

- 2.2. D2 discloses the deposition of GaAs doped with dopants. The dopants are added to the As or the Ga raw material, viz. bis-cyclopentadienyl magnesium (Figure 5 and column 7, line 16 to column 8, line 9).

In the light of D2, the subject-matter of claims 1 to 25 is not new.

- 2.3. D3 discloses the use of the precursors Cp₂Mg or bis-cyclopentadienyl magnesium and TeESi or tetraethylsilane (TESi in the present application).
- 2.4. D4 discloses the deposition of GaAs doped with dopants, like bis-cyclopentadienyl magnesium and tetraethylsilane (Table 1). The dopants are added to the As or the Ga raw material (Figure 5 and page 6, lines 6 to 18).
3. Document D1, which is considered to represent the most relevant state of the art, discloses a doping method from which the subject-matter of claim 21 differs in that bis-cyclopentadienyl magnesium and tetraethylsilane are used as dopant precursors.



The use of these precursors is either described in documents D2, D3 and D4 or come further within the scope of the customary practice followed by persons skilled in the art, especially as the advantages thus achieved can be readily contemplated in advance.

Consequently, the subject-matter of claims 21 appears to lack an inventive step (Art. 52(1) and 56 EPC).

4. Claim 22 is a product-by-process claims.

According to the EPO practice, such a claim is admissible only if the products as such fulfil the requirements of patentability, i.e. inter alia that they are new and inventive.

A product is not rendered novel merely by the fact that it is produced by means of a different or even a new process (see Guidelines, C-III, 4.7b).

It is assumed that the applicant agrees that a doped semiconductor material per se was prior art (viz. Doc. D1 to D4) before the priority date.

Thus claim 22 is open to objection for lack of novelty (Article 52(1) and 54(1,2) EPC).

In this connection it is pointed out that according to Article 64(2), if the subject matter of an European Patent is a process, the protection conferred by the patent extends to the products directly obtained by such process.

Additionally, claim 22 does not meet the requirements of Article 84 EPC in that the matter for which protection is sought is not defined.

The claim attempts to define the subject-matter in terms of the result to be achieved, viz. plural type of impurities being disposed closely with each other. Such a definition is only allowable under the conditions elaborated in the Guidelines C-III, 4.7.

In this instance, however, such a formulation is not allowable because it appears possible to define the subject-matter in more concrete terms, viz. in terms of how the effect is to be achieved.

5. Similar objections are raised against product-by-process claim 23.



6. In the European patent procedure, claims to a system are regarded as claims to an apparatus.

The feature "a control means for [...] controlling further in such that the raw material gases [...] are supplied into said reaction [...] in a pulsed manner" in apparatus claim 24 relates to a method of using the apparatus rather than clearly defining the apparatus in terms of its technical features

The intended limitations are therefore not clear from this claim, contrary to the requirements of Article 84 EPC.

A similar objection is raised against claim 25.

7. The applicant is requested to file new claims which take account of the above comments.
8. When filing amended claims the applicant should at the same time bring the description into conformity with the amended claims. Care should be taken during revision, especially of the introductory portion and any statements of problem or advantage, not to add subject-matter which extends beyond the content of the application as originally filed (Article 123(2) EPC).
- 8.1. To meet the requirements of Rule 27(1)(b) EPC, the documents D1 and D2 should be identified in the description and the relevant background art disclosed therein should be briefly discussed.
- 8.2. The vague and imprecise statements in the description on page 28, third and fourth paragraph implies that the subject-matter for which protection is sought may be different to that defined by the claims, thereby resulting in lack of clarity of the claims (Article 84 EPC) when used to interpret them (see the Guidelines, C-III, 4.3a).
These statements should therefore be amended to remove this inconsistency.
- 8.3. The last paragraph on page 28 appears to be superfluous. Here, reference is made to the priority document of the present application.

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IHR ZEICHEN / YOUR REF

UNSER ZEICHEN / OUR REF

DATUM / DATE

EP22290TSKKgb

02.07.2004

Application No: 01 121 026.7-2119

Applicant: RIKEN

In response to the Official Communication dated February 24, 2004:

The Primary Examiner's arguments in the afore-mentioned Official Communication have been carefully considered. However, it appears that the invention as laid down in the original claims distinguishes in a crucial point from the disclosure of specifically cited references US 5,693,139 (D1) and US 5,338,389 (D2) as pointed out in the following:

Cited reference D1 discloses a method to grow doped semiconductor monolayers using a vapor phase epitaxial growth process for growing semiconductor crystals and films. As described in column 3, lines 37 to 67, said known process involves the introduction of a first source gas into a growth chamber to grow a first monolayer, the introduction of a second (different) source gas for growing a further monolayer, the introduction of an impurity gas to cause impurities to enter into sites of the second monolayer, and repeating the afore-mentioned three steps. Hence, cited reference D1 teaches to produce a compound semiconductor crystal layer being grown in monolayers, wherein at least one of the monolayers is doped with a predetermined impurity.

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More precisely, it is stated in column 8, lines 33 to 57 of D1, that the doped layer can be a p-type growth layer using Zn as dopant. Alternatively, the doped layer can be formed as an n-type growth layer. It is further outlined in column 9, lines 34 to 59, that silane (SiH_4) is introduced as an impurity gas in four cycles shown in Fig. 7b to produce a monolayer being doped with one specific kind of impurity. Moreover, reference is made to column 11, line 29, in conjunction with Figs. 11 and 12 of D1, where it is pointed out that molecular layer epitaxy with n-type impurity doping is carried out. The p-type doping is described in column 12, lines 45 onwards.

The afore-mentioned text passages confirm that cited reference D1 discloses to either carry out n-type impurity doping or to carry out p-type impurity doping such that distinct n-doped or p-doped layers are produced.

The same holds for cited reference D2 which quotes Mr. Jun-ichi Nishizawa as inventor, who is likewise one of the inventors quoted in D1. The method disclosed in cited reference D2 basically corresponds to the one disclosed in cited reference D1. Specifically, the doping is carried out either with n-type impurities or with p-type impurities.

The difference between the invention and the disclosure of cited references D1 and D2 consists in that plural types of impurity raw materials are supplied within one cycle as indicated in original claim 1, while D1 and D2 suggest to supply only one type of impurity raw material within one cycle. Moreover, said plural types of impurity raw materials are supplied at close timings in a pulsed manner according to the invention.

Specifically, the plural types of impurity raw materials used according to the invention can be donors and acceptors as disclosed on page 14, second paragraph of the specification.

The fundamental difference between the invention and the prior art as disclosed in cited references D1 and D2 is reflected in original independent claims 2 and 3 by the formulation according to which the plural types of impurity raw materials are supplied before the supply of the other predetermined types of crystal raw materials is started. Said feature has its corresponding feature in independent method claim 21 in the formulation according to which the supply of NH_3 is started at a timing at which the supply of TESI is finished. The

afore-mentioned features of claims 2, 3 and 21 correspond to the distinguishing feature of claim 1 which indicates that more than one type of impurity raw material is supplied at close timings in a pulsed manner within one cycle and, hence, before a further crystal raw material is supplied.

Therefore, the subject-matters of original claims 1, 2, 3 and 21 should be new with respect to cited references D1 and D2.

The general teaching underlying the invention, namely to supply more than one type of impurity raw material within one cycle, allows to co-dope a layer with both donors and acceptors. Thereby, an acceptor level can be reduced by creating a complex made up of two acceptors and one donor in a crystal as shown in Figs. A and B attached to this submission. By the inventive method, it is possible to achieve a GaN semiconductor having a hole concentration in the range of 10^{19} .

The formation of said acceptor and donor complexes is difficult since the donors and the acceptors can hardly move in the crystals such that there is little possibility that a complex thereof is created. The donors and acceptors are therefore supplied into the crystal in a scattered manner such that the donor effect and the acceptor effect damp each other.

Only by supplying the different impurity raw materials at close timings in a pulsed manner within one cycle, it is possible to introduce the acceptors and donors into one atomic layer or into two adjacent atomic layers. In this conjunction, the inventors of the present invention have found out that the atoms move very actively on the crystal surface such that if the donors and acceptors are supplied within one cycle a desired donor/acceptor complex is readily formed by such behavior. This is described on page 25 onwards of the specification and specifically shown in Figs. 3 and 8 which illustrates a semiconductor having Ga-layers doped with Mg-Si respectively followed by an undoped N-layer. The pulsed supply pattern to achieve such semiconductors is shown in Fig. 27 of the present application.

As none of the cited references discloses or even contains a hint which could possibly point to the use of more than one impurity raw material to be supplied within one cycle at close

timings in a pulsed manner, the methods according to original claims 1, 2, 3 and 21 should not only be new but also involve an inventive step.

It is respectfully requested that a further Official Communication be issued in which the Primary Examiner's general consent to the gist of the invention as laid down in the original claims is stated. A revised complete set of claims will be submitted immediately thereafter so as to take into account the formal objections raised in the Official Communication. Moreover, the specification will be revised so as to acknowledge cited references D1 and D2.

A handwritten signature in black ink, appearing to be 'T. Schuster', with a stylized, flowing script.

(T. Schuster)

Encl: Figs. A and B

Acceptor and Donor Complex

○ Ga ● acceptor ● donor

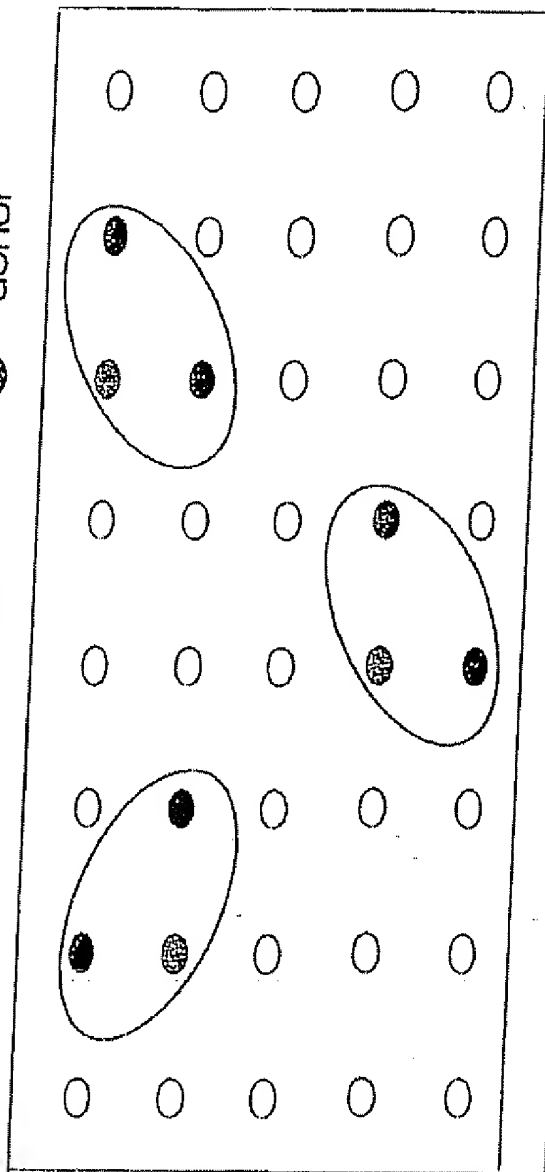


FIG. A

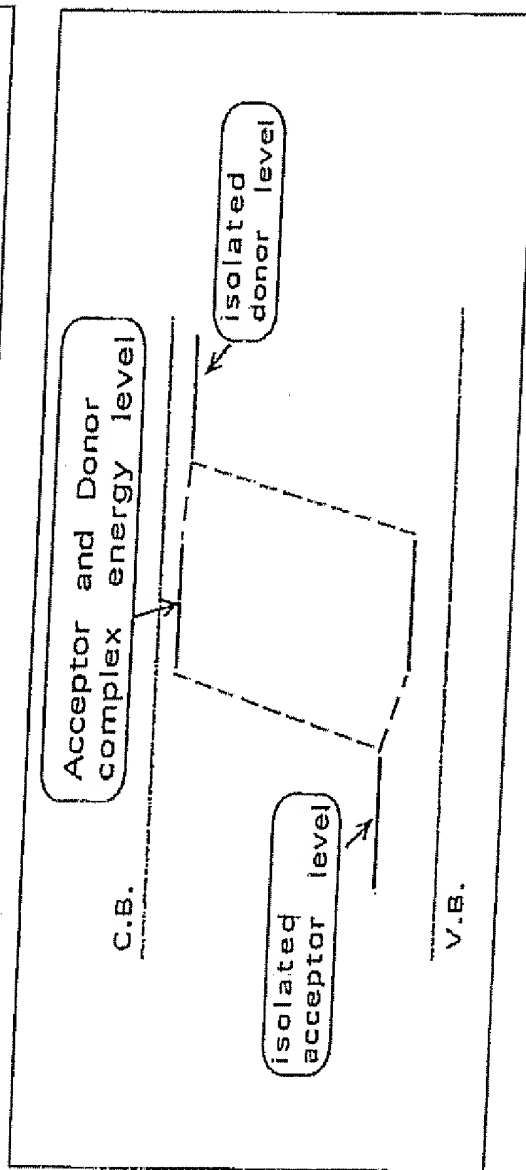


FIG. B



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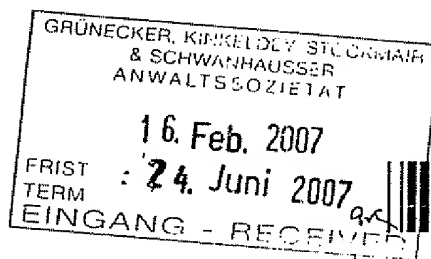
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| | | |
|---------------------------------------|-----------------------|--------------------|
| Application No 01 121 026.7 - 2119 | Ref. EP22290-011/w | Date 14.02.2007 |
| Applicant RIKEN | | |

Communication pursuant to Article 96(2) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(1) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 78(2) and 83(2) and (4) EPC.

One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (Rule 36(1) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Article 96(3) EPC).



Kiliaan, Sven
Primary Examiner
for the Examining Division

Enclosure(s): 2 page/s reasons (Form 2906)

Datum
Date 14.02.2007Blatt
Sheet 1
FeuilleAnmelde-Nr.:
Application No.: 01 121 026.7
Demande n°:

The examination is being carried out on the **following application documents:**

Description, Pages

1-28 as originally filed

Claims, Numbers

1-25 as originally filed

Drawings, Figures

1-10 as originally filed

1. Your reply of 02/07/2004 has been considered.
2. The examiner agrees with the applicant that in D1 and D2 doping is carried out with n-type impurities **or** with p-type impurities, whereas in the application present on file doping is carried out with n-type and p-type impurities resulting in a co-doped semiconductor layer.

Furthermore, the applicant has pointed out that plural types of impurity raw materials can be donors **and** acceptors (page 14, 2nd. paragraph).

3. However, claims 1 to 3 use the phrase "each of plural types of impurity raw materials".

This phrase is unclear, because the exact meaning of "plural types" is unclear.

In the communication of 24/02/2004, it was argued that D1 discloses the simultaneous introduction of dimethylcadmium (DMCd) and dimethylzinc (DMZn). These materials are considered to be plural type of impurity raw materials. Figure 11 of D1 shows that the impurity raw materials are being supplied at close timings in a pulsed manner within one cycle.

Consequently, at present the novelty objection raised against claims 1 to 3 is maintained.

The claims 4 to 11 are directed to well-known crystal raw materials and are therefore also considered to lack novelty.

In the light of the arguments above, the novelty and clarity objections against claim 22 are maintained.

4. The subject-matter of claims 12 to 21 and 23 appears to be new



- 4.1. Claims 12 to 20 are directed to the impurity raw materials being a p-type impurity raw material **and** n-type impurity raw material.
- 4.2. None of the documents mentioned in the search report refer to the claimed impurity doping method.
- Consequently, claims 21 and 23 appears to be new.
5. The clarity objections raised against claims 24 and 25 are maintained.
6. The applicant is invited to file new claims which take account of the above comments.
7. When filing amended claims the applicant should at the same time bring the description into conformity with the amended claims. Care should be taken during revision, especially of the introductory portion and any statements of problem or advantage, not to add subject-matter which extends beyond the content of the application as originally filed (Article 123(2) EPC).
- 7.1. To meet the requirements of Rule 27(1)(b) EPC, the documents D1 and D2 should be identified in the description and the relevant background art disclosed therein should be briefly discussed.
- 7.2. The vague and imprecise statements in the description on page 28, third and fourth paragraph implies that the subject-matter for which protection is sought may be different to that defined by the claims, thereby resulting in lack of clarity of the claims (Article 84 EPC) when used to interpret them (see the Guidelines, C-III, 4.3a).
These statements should therefore be amended to remove this inconsistency.
- 7.3. The last paragraph on page 28 appears to be superfluous. Here, reference is made to the priority document of the present application.

European Patent Application No. 01 121 026.7
Applicant: RIKEN
Our Ref.: EP22290MD142
Date: DRAFT

New Claims

(for replacing all claims as on file)

1. An impurity doping method for semiconductor wherein a crystal layer made of crystal raw materials is doped with impurities, comprising:

~~each of plural~~ a supply of different doping types of impurity raw materials ~~being supplied at close timings in a pulsed manner within one cycle wherein all types of said crystal raw materials are supplied in one time each in the case when plural types of said crystal raw materials are alternately supplied in a pulsed manner with maintaining each of predetermined purge times.~~

2. ~~An~~ The impurity doping method for semiconductor according to claim 1, wherein ~~a crystal layer made of crystal raw materials is doped with impurities, comprising: each of plural~~ said different doping types of impurity raw materials being supplied at close timings in a pulsed manner either at the same time of, or after starting a supply of predetermined types of crystal raw materials as well as before starting a supply of the other predetermined types of crystal raw materials within said one cycle ~~wherein all types of said plural types of crystal raw materials are supplied in one time each in the case when plural types of said crystal raw materials are alternately supplied in a pulsed manner with maintaining each of predetermined purge times.~~

3. ~~An~~ The impurity doping method for semiconductor according to claim 2, wherein ~~a crystal layer made of crystal raw materials is doped with impurities, comprising: said different doping types of impurity raw materials comprises~~ a first impurity raw material of a first doping type and a second impurity material of a second doping type being different to the first doping type, which are being supplied at close timings in a pulsed manner either at the same time of, or after starting a supply of said a first crystal raw material as well as before starting a supply of said a second crystal raw material within one cycle wherein said first and second crystal raw materials are supplied in one time each in the case when said first crystal raw material is supplied alternately with said second crystal raw material in a pulsed manner with maintaining each of predetermined purge times.

4. ~~An~~ The impurity doping method for semiconductor as ~~claimed in~~ according to claim 3, wherein:

a supply of said first impurity raw material is started in synchronous with starting a supply of said first crystal raw material, a supply of said second impurity raw material is started after finishing the supply of said first impurity raw material, and the supply of said second impurity raw material is finished before starting the supply of said second crystal raw material.

5. ~~An~~ The impurity doping method for semiconductor as ~~claimed in~~ according to claim 3, wherein:

there is a period of time wherein said first impurity raw material is supplied with said second impurity raw material at the same time.

6. ~~An~~ The impurity doping method for semiconductor as ~~claimed in~~ according to any of claims 1 to 5, wherein:

a crystal raw material supplied precedently within said one cycle in said crystal raw materials is at least one member selected from the group consisting of Ga, Al, In, B, Zn, and Cd, while a crystal raw material supplied latterly within said one cycle is at least one member selected from the group consisting of N, As, P, S, Se, and Te.

7. ~~An impurity doping method for semiconductor as claimed in claim 2 wherein:~~

~~a crystal raw material supplied precedently within said one cycle in said crystal raw materials is at least one member selected from the group consisting of Ga, Al, In, B, Zn, and Cd, while a crystal raw material supplied latterly within said one cycle is at least one member selected from the group consisting of N, As, P, S, Se, and Te.~~

8. ~~An impurity doping method for semiconductor as claimed in claim 3 wherein:~~

~~a crystal raw material supplied precedently within said one cycle in said crystal raw materials is at least one member selected from the group consisting of Ga, Al, In, B, Zn, and Cd, while a crystal raw material supplied latterly within said one cycle is at least one member selected from the group consisting of N, As, P, S, Se, and Te.~~

~~9. An impurity doping method for semiconductor as claimed in claim 4 wherein:
a crystal raw material supplied precedently within said one cycle in said crystal raw
materials is at least one member selected from the group consisting of Ga, Al, In,
B, Zn, and Cd, while a crystal raw material supplied latterly within said one cycle is
at least one member selected from the group consisting of N, As, P, S, Se, and Te.~~

~~10. An impurity doping method for semiconductor as claimed in claim 5 wherein:
a crystal raw material supplied precedently within said one cycle in said crystal raw
materials is at least one member selected from the group consisting of Ga, Al, In,
B, Zn, and Cd, while a crystal raw material supplied latterly within said one cycle is
at least one member selected from the group consisting of N, As, P, S, Se, and Te.~~

~~11. An impurity doping method for semiconductor as claimed in claim 6 wherein:
said different doping types of impurity raw materials are a p-type impurity raw
material and an n-type impurity raw material.~~

~~12. An impurity doping method for semiconductor as claimed in claim 2 wherein:
said impurity raw materials are a p-type impurity raw material and an n-type impu-
rity raw material.~~

~~13. An impurity doping method for semiconductor as claimed in claim 3 wherein:
said impurity raw materials are a p-type impurity raw material and an n-type impu-
rity raw material.~~

~~14. An impurity doping method for semiconductor as claimed in claim 4 wherein:
said impurity raw materials are a p-type impurity raw material and an n-type impu-
rity raw material.~~

~~15. An impurity doping method for semiconductor as claimed in claim 5 wherein:
said impurity raw materials are a p-type impurity raw material and an n-type impu-
rity raw material.~~

~~16. An impurity doping method for semiconductor as claimed in claim 6 wherein:
said impurity raw materials are a p-type impurity raw material and an n-type impu-
rity raw material.~~

~~17. An impurity doping method for semiconductor as claimed in claim 7 wherein:
said impurity raw materials are a p-type impurity raw material and an n-type impu-
rity raw material.~~

~~said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.~~

~~17. An impurity doping method for semiconductor as claimed in claim 7 wherein: said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.~~

~~18. An impurity doping method for semiconductor as claimed in claim 8 wherein: said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.~~

~~19. An impurity doping method for semiconductor as claimed in claim 9 wherein: said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.~~

~~20. An impurity doping method for semiconductor as claimed in claim 10 wherein: said impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.~~

~~218. An~~ The impurity doping method for semiconductor according to any of claims 1 to 7, wherein ~~a crystal layer made of crystal raw materials is doped with impurities, comprising:~~

said different doping types of impurity raw materials are comprised of (Cp)2Mg being a first impurity raw material and TESi being a second impurity raw material.

said plural types of crystal raw materials are comprised of TMGa being a first crystal raw material and NH3 being a second crystal raw material;

a said cycle composed comprises the steps of:

(a) first step wherein a supplying of TMGa and (Cp)2Mg is started at a first timing,

(b) finishing and the supply of TMGa and (Cp)2Mg is finished at a second timing at which the supply of TMGa and (Cp)2Mg for a predetermined period of time was completed;

~~(c) a second step wherein a supplying of TESI is started either immediately after, or after the second timing at which the supply of TMGa and (Cp)₂Mg was finished,~~

~~(d) finishing and the supply of TESI is finished at a third timing at which the supply of TESI for a predetermined period of time was completed,~~

~~(e) a third step wherein a supplying of NH₃ is started either immediately after, or after the third timing at which the supply of TESI is finished,~~

~~(f) finishing and the supply of NH₃ is finished at a fourth timing at which the supply of NH₃ for a predetermined period of time was completed, and~~

~~(g) starting a fourth step wherein a predetermined purge time is started after the supply of NH₃ is finished at the fourth timing at which the supply of NH₃ was completed, and~~

~~(h) finishing said predetermined purge time is finished at a fifth timing, and said cycle being repeated a desired number of times.~~

229. A semiconductor material prepared by doping comprising a crystal layer with plural different doping types of impurities comprising:

said plural types of impurities being disposed closely with each other in said crystal layer at a predetermined ratio.

2310. A The semiconductor material according to claim 9, wherein prepared by doping a said crystal layer is made of Ga and comprises with Mg and Si comprising: Mg and Si being different doping types of impurities, which are being disposed closely with each other in said crystal layer made of Ga at a predetermined ratio.

2411. An impurity doping system for semiconductor wherein a crystal layer made of crystal raw materials is doped with impurities, comprising

a reaction tube to the interior of which is disposed a substrate,

a plurality of pipes being designed for supplying raw material gases of the crystal raw materials as well as and being designed for supplying raw material gases of impurity raw materials into said reaction tube, respectively;

gas valves mounted on said plurality of pipes, respectively;

a flow rate setting means being designed for setting out each flow rate of the raw material gases of said crystal raw materials and the raw material gases of said

impurity raw materials flowing through said plurality of pipes, respectively, to a predetermined value;

a heating means being designed for heating said substrate disposed inside said reaction tube; and

a control means being designed for controlling

closing motions of said gas valves,

flow rates set out by said flow rate setting means,

heating of said substrate by means of said heating means, and

~~controlling further in such that a supply of~~ the raw material gases of said crystal raw materials and of the raw material gases of said impurity raw materials are supplied into said reaction tube through said pipes at predetermined timings, respectively, in a pulsed manner.

~~2512. An~~ The impurity doping system for semiconductor according to claim 11, wherein ~~a crystal layer made of crystal raw materials is doped with impurities, comprising:~~

~~a reaction tube to the interior of which is disposed a substrate;~~

said plurality of pipes comprises

a first pipe being designed for supplying NH₃ gas into said reaction tube together with H₂ gas being a carrier gas;

a second pipe being designed for supplying TMGa, (Cp)₂Mg, and TESI into said reaction tube together with H₂ gas being a carrier gas, and

a third pipe being designed for supplying N₂ gas being a carrier gas into said reaction tube;

said gas valves are mounted on said first, second, and third pipes, respectively;

~~a~~ said flow rate setting means ~~for setting~~ sets out each flow rate of gases flowing through said first, second, and third pipes, respectively, to a predetermined value;

~~a heating means for heating said substrate disposed inside said reaction tube; and~~

~~a~~ said control means controls ~~for controlling closing motions of said gas valves, flow rates set out by said flow rate setting means, heating of said substrate by means of said heating means, and controlling further in such that a supply of~~

NH₃ gas ~~is supplied in~~ said reaction tube through said first pipe, a supply of TMGa, of (Cp)₂Mg, and of TESI are ~~supplied into~~ said reaction tube through said second pipe, and a supply of N₂ gas ~~is supplied into~~ said reaction tube through said third pipe at predetermined timings, respectively, in a pulsed manner.

New Claims

(for replacing all claims as on file)

1. An impurity doping method for semiconductor wherein a crystal layer made of crystal raw materials is doped with impurities, comprising
a supply of different doping types of impurity raw materials at close timings in a pulsed manner within one cycle wherein all types of said crystal raw materials are supplied in one time each in the case when plural types of said crystal raw materials are alternately supplied in a pulsed manner with maintaining each of predetermined purge times.
2. The impurity doping method for semiconductor according to claim 1, wherein said different doping types of impurity raw materials being supplied at close timings in a pulsed manner either at the same time of, or after starting a supply of predetermined types of crystal raw materials as well as before starting a supply of the other predetermined types of crystal raw materials within said one cycle.
3. The impurity doping method for semiconductor according to claim 2, wherein said different doping types of impurity raw materials comprises a first impurity raw material of a first doping type and a second impurity material of a second doping type being different to the first doping type, which are supplied at close timings in a pulsed manner either at the same time of, or after starting a supply of a first crystal raw material as well as before starting a supply of a second crystal raw material within one cycle wherein said first and second crystal raw materials are supplied in one time each in the case when said first crystal raw material is supplied alternately with said second crystal raw material in a pulsed manner with maintaining each of predetermined purge times.
4. The impurity doping method for semiconductor according to claim 3, wherein:
a supply of said first impurity raw material is started in synchronous with starting a supply of said first crystal raw material, a supply of said second impurity raw material is started after finishing the supply of said first impurity raw material, and

the supply of said second impurity raw material is finished before starting the supply of said second crystal raw material.

5. The impurity doping method for semiconductor according to claim 3, wherein there is a period of time wherein said first impurity raw material is supplied with said second impurity raw material at the same time.

6. The impurity doping method for semiconductor according to any of claims 1 to 5, wherein:

a crystal raw material supplied precedently within said one cycle in said crystal raw materials is at least one member selected from the group consisting of Ga, Al, In, B, Zn, and Cd, while a crystal raw material supplied latterly within said one cycle is at least one member selected from the group consisting of N, As, P, S, Se, and Te.

7. The impurity doping method for semiconductor according to any of claims 1 to 6, wherein:

said different doping types of impurity raw materials are a p-type impurity raw material and an n-type impurity raw material.

8. The impurity doping method for semiconductor according to any of claims 1 to 7, wherein

said different doping types of impurity raw materials are comprised of (Cp)₂Mg being a first impurity raw material and TESI being a second impurity raw material,

said plural types of crystal raw materials are comprised of TMGa being a first crystal raw material and NH₃ being a second crystal raw material;

said cycle comprises the steps of:

(a) supplying TMGa and (Cp)₂Mg at a first timing,

(b) finishing the supply of TMGa and (Cp)₂Mg at a second timing at which the supply of TMGa and (Cp)₂Mg for a predetermined period of time was completed;

(c) supplying TESI either immediately after, or after the second timing at which the supply of TMGa and (Cp)₂Mg was finished,

(d) finishing the supply of TESI at a third timing at which the supply of TESI for a predetermined period of time was completed,

(e) supplying NH₃ either immediately after, or after the third timing at which the supply of TESI is finished,

(f) finishing the supply of NH₃ at a fourth timing at which the supply of NH₃ for a predetermined period of time was completed,

(g) starting a predetermined purge time after the supply of NH₃ at the fourth timing at which the supply of NH₃ was completed,

(h) finishing said predetermined purge time at a fifth timing; and
said cycle being repeated a desired number of times

9. A semiconductor material comprising a crystal layer with different doping types of impurities being disposed closely with each other in said crystal layer at a predetermined ratio.

10. The semiconductor material according to claim 9, wherein said crystal layer is made of Ga and comprises Mg and Si being different doping types of impurities, which are disposed closely with each other in said crystal layer made of Ga at a predetermined ratio.

11. An impurity doping system for semiconductor wherein a crystal layer made of crystal raw materials is doped with impurities, comprising:

a reaction tube to the interior of which is disposed a substrate;

a plurality of pipes being designed for supplying raw material gases of the crystal raw materials and being designed for supplying raw material gases of impurity raw materials into said reaction tube, respectively;

gas valves mounted on said plurality of pipes, respectively;

a flow rate setting means being designed for setting out each flow rate of the raw material gases of said crystal raw materials and the raw material gases of said impurity raw materials flowing through said plurality of pipes, respectively, to a predetermined value;

a heating means being designed for heating said substrate disposed inside said reaction tube; and

a control means being designed for controlling

closing motions of said gas valves,
flow rates set out by said flow rate setting means,
heating of said substrate by means of said heating means, and
a supply of the raw material gases of said crystal raw materials and of the raw material gases of said impurity raw materials into said reaction tube through said pipes at predetermined timings, respectively, in a pulsed manner

12. The impurity doping system for semiconductor according to claim 11, wherein said plurality of pipes comprises

a first pipe being designed for supplying NH_3 gas into said reaction tube together with H_2 gas being a carrier gas;

a second pipe being designed for supplying TMGa , $(\text{Cp})_2\text{Mg}$, and TESi into said reaction tube together with H_2 gas being a carrier gas; and

a third pipe being designed for supplying N_2 gas being a carrier gas into said reaction tube;

said gas valves are mounted on said first, second, and third pipes, respectively;

said flow rate setting means sets out each flow rate of gases flowing through said first, second, and third pipes, respectively, to a predetermined value; and

said control means controls a supply of NH_3 gas in said reaction tube through said first pipe, a supply of TMGa , of $(\text{Cp})_2\text{Mg}$, and of TESi into said reaction tube through said second pipe, and a supply of N_2 gas into said reaction tube through said third pipe at predetermined timings, respectively, in a pulsed manner.